

EMERGENCY WHOLE-BLOOD USE IN THE FIELD: A SIMPLIFIED PROTOCOL FOR COLLECTION AND TRANSFUSION

Geir Strandenes,^{*†} Marc De Pasquale,[‡] Andrew P. Cap,[§] Tor A. Hervig,[†] Einar K. Kristoffersen,[†] Matthew Hickey,^{||} Christopher Cordova,^{||} Olle Berseus,^{**} Håkon S. Eliassen,[†] Logan Fisher,^{††} Steve Williams,^{‡‡} and Philip C. Spinella^{§,§§}

**Norwegian Naval Special Operation Commando; and; †Department of Immunology and Transfusion Medicine, Haukeland University Hospital, and Institute of Clinical Science, University of Bergen, Bergen, Norway; ‡Deployment Medicine International, Gig Harbor, Washington; §US Army Institute of Surgical Research, Fort Sam Houston, Texas; ||Naval Special Warfare Command, San Diego, California; ||Specialist Corps, US Army, Keller Army Community Hospital, West Point, New York; **Department of Transfusion Medicine, Örebro University Hospital, Örebro, Sweden; ††NSWDG US Navy, Virginia Beach, Virginia; ‡‡Medical Operations Royal Caribbean Cruises Ltd.; and §§Department of Pediatrics, Division of Critical Care, Washington University in St. Louis, St. Louis, Missouri*

Received 19 Sep 2013; first review completed 8 Oct 2013; accepted in final form 10 Dec 2013

ABSTRACT—Military experience and recent *in vitro* laboratory data provide a biological rationale for whole-blood use in the treatment of exsanguinating hemorrhage and have renewed interest in the reintroduction of fresh whole blood and cold-stored whole blood to patient care in austere environments. There is scant evidence to support, in a field environment, that a whole blood–based resuscitation strategy is superior to a crystalloid/colloid approach even when augmented by a limited number of red blood cell (RBC) and plasma units. Recent retrospective evidence suggests that, in this setting, resuscitation with a full complement of RBCs, plasma, and platelets may offer an advantage, especially under conditions where evacuation is delayed. No current evacuation system, military or civilian, is capable of providing RBC, plasma, and platelet units in a prehospital environment, especially in austere settings. As a result, for the vast minority of casualties, in austere settings, with life-threatening hemorrhage, it is appropriate to consider a whole blood–based resuscitation approach to provide a balanced response to altered hemostasis and oxygen debt, with the goal of reducing the risk of death from hemorrhagic shock. To optimize the successful use of fresh whole blood/cold-stored whole blood in combat field environments, proper planning and frequent training to maximize efficiency and safety will be required. Combat medics will need proper protocol-based guidance and education if whole-blood collection and transfusion are to be successfully and safely performed in austere environments. In this article, we present the Norwegian Naval Special Operation Commando unit–specific remote damage control resuscitation protocol, which includes field collection and transfusion of whole blood. This protocol can serve as a template for others to use and adjust for their own military or civilian unit–specific needs and capabilities for care in austere environments.

KEYWORDS—Shock, prehospital, remote, damage control, trauma, combat

INTRODUCTION

Most deaths on the battlefield today are nonsurvivable, defined as “no measure taken will save the life of the severely wounded soldier” (1). However, among the group of potentially salvageable fatalities, hemorrhage is the leading cause of death (2). The resuscitation of patients with traumatic hemorrhagic shock has changed toward a model known as “damage control resuscitation” (DCR) (3). The application of DCR in the prehospital setting is termed “remote damage control resuscitation” (RDCR) (4). Therapeutic options applied in RDCR can change as the challenges and timeline to reaching higher echelons of care are increased (e.g., military operations

in far-forward locations). Blood components of red blood cell (RBC), plasma, and platelet units in addition to whole blood are used to provide hemostatic resuscitation within the overarching concept of DCR (3).

When the tactical situation and logistical obstacles do not permit implementation of a blood component–based resuscitation strategy for traumatic hemorrhagic shock, an alternative approach is required. This approach must be simple and safe to perform. Because the early treatment of oxygen debt and coagulopathy is important in preventing death from exsanguination, we suggest that the use of whole blood is an appropriate alternative in austere settings where all blood components are not available. Whole blood is perhaps the most appropriate product for hemostatic resuscitation, which is defined as, “the early use of a balanced amount of RBCs, plasma, and platelets” (5). The challenges to making whole blood available for hemostatic resuscitation in RDCR are to develop feasible and safe “collection-and-use” protocols.

Historical reports on the use of whole blood in World War II and Vietnam show that it was the preferred resuscitation product

Address reprint requests to Geir Strandenes, MD, Helse Bergen Haukeland University Hospital, Bergen, Norway. E-mail: geir@docfish.no.

Conflicts of Interest: For Spinella, TerumoBCT, Entegriion, Octapharma.

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the US Department of the Army or the US Department of Defense.

DOI: 10.1097/SHK.0000000000000114

Copyright © 2014 by the Shock Society

Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 01 MAY 2014		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Emergency Whole Blood use in the Field: A Simplified Protocol for Collection and Transfusion				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Strandenes G., De Pasquale M., Cap A. P., Hervig T. A., Kristoffersen E., Hickey M., Cordova C., Berseus O., Eliassen H., Fisher L., Williams S., Spinella P.,				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US Army Institute of Surgical Research, JBSA Fort Sam Houston, Texas				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 8	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

SPECIAL CONSIDERATIONS:

This protocol is designed for Marinejegerkommandoen, Norwegian Naval Special Operation Commando (NORNAVSOC) but can be adapted to the needs of other units.

The safety and efficacy measurements such as: pre-screening, training, marking and preparations are based on feasibility and the thorough knowledge of the unit. In Norway, medics and other military medical personnel provide health care on delegation from a specific Chief Medical Officer (CMO). This implies that personnel outside this unit may use this protocol but they will not work on the same delegation of authority.

The most important skill needed to perform this procedure is the experience to identify patients who need whole blood resuscitation.

The most important rule is to give blood type A to A and blood type O to everybody else. It is recommended to use type O blood from "low titer" donors for non type O patients or patients where the blood type cannot be confidently determined. Any administration of an incompatible blood type is likely to be fatal.

This protocol can only be utilized by personnel that have completed both the theoretical and practical part of the emergency transfusion training program held at NORNAVSOC. Other units adopting this protocol should institute comparable training programs.

FIG. 1. Special considerations.

compared with the use of individual blood components such as plasma (6, 7). Over time, blood product availability shifted from whole blood to individual components in an effort to conserve blood as a resource and provide single blood components for specific deficiencies (anemia, thrombocytopenia, etc.). This resulted in the elimination of whole blood as a blood product that was available for patients with severe bleeding, except in very limited circumstances such as pediatric cardiac surgery. Recent military experience and *in vitro* laboratory data provide a biological rationale for whole-blood use in the treatment of exsanguinating hemorrhage and have renewed interest in the reintroduction of warm whole blood (WWB) stored at 22°C for less than 24 h and cold-stored whole blood (CWB) stored at 4°C for as long as 21 days (preferred <10 days of storage) to patient care in austere environments (8, 9).

Currently, the predominant resuscitation fluids used for patients with exsanguinating injuries in the field are crystalloids and colloids. Uncommonly, RBC and plasma units are available in limited supply. No current evacuation system, military or civilian, is capable of providing RBC, plasma, and platelet units in a prehospital environment. As a result, in austere environments, for casualties with life-threatening hemorrhage, it is appropriate to consider a whole blood-based resuscitation approach to provide a balanced response to altered hemostasis and oxygen debt, with the goal of reducing the risk of death from hemorrhagic shock.

Although there is scant evidence to support that a whole blood-based resuscitation strategy is superior to a crystalloid/colloid approach, even when augmented by a limited number of RBC and plasma units, recent retrospective evidence

QUICK REFERENCE PROTOCOL FOR PRE-DONATED BLOOD:

Plasma first protocol should be initiated prior to whole blood transfusion.

- A. Identify recipient's blood type with accuracy - NO MISTAKES!!
- B. Retrieve a blood bag from the container—preferably type O low titer.
- C. ***When type O is transfused it is recommended to continue with type O and not go back to type specific whole blood transfusion.***
- D. Heat the blood with a fluid warmer.
- E. Administer 1g of tranexamic acid to the patient and start antibiotic treatment if not done already.
- F. Responsible medic double-checks blood type one more time before administering whole blood.
- G. Administer blood IO or IV following RDCR hypotensive principles.

QUICK REFERENCE PROTOCOL FOR BUDDY TRANSFUSION:

Initiate plasma protocol prior to infusing whole blood.

- A. Identify donor's and recipient's blood type with accuracy - NO MISTAKES!!
- B. ***GIVE THE PATIENT WHOLE BLOOD WITH THE SAME BLOOD TYPE. IF THAT IS NOT AVAILABLE, USE TYPE O (preferably low titer)! NO OTHER COMBINATIONS CAN BE GIVEN!***
- C. Each donor marks the blood bag themselves and this is double-checked by the soldier drawing the blood.
- D. Draw blood; apply loose tourniquet on upper arm, tie a loose knot on blood bag tubing, puncture vein, secure needle, hold the bag and fill to 450ml +/- 50ml.
- E. When bag is filled, the pre-tied knot is tightened and needle removed from donor.
- F. Administer 1g of tranexamic acid to the patient and start antibiotic treatment if not done already.
- G. Responsible medic double-checks blood type one more time before administering whole blood.
- H. Administer blood IO or IV following hypotensive RDCR principles.

FIG. 2. Quick reference protocols for predonated blood and buddy transfusion.

EQUIPMENT LIST RDCR PROTOCOL NORNAVSOC

TOTAL WEIGHT 780 GR/0,8 KG

- BLOOD COLLECTION BAG-SINGLE PACKED TERUMO CPDA
- INFUSION SET – SINGLE SPIKE BRAUN
- I.V CANNULA- 16 GAUGE VENEFLON
- ALCOHOL SWAB
- FAST ONE I.O NEEDLE
- FREEZE DRIED PLASMA – LYOPLS-N-W (SINGLE DONOR) AB
- ELDON CARD
- MULTIPLE RAPID TEST FOR HIV/HEPB/HEPC(MEDMIRA)
- MARKER PEN WATER PROOF
- SYRINGE 10CC/1CC
- SALINE FLUSH 10CC
- TXA 100MG/CC-2X5CC = 1GR
- PARACORD
- PERSONAL FIELD DONORCARD
- VENOUS RESTRICTION BAND
- LACTATE SCOUT – LACTATE ANALYSER

FIG. 3. Equipment list required for NORVASC RDCR protocol.

suggests that resuscitation with the full compliment of RBCs, plasma, and platelets may offer an advantage (10, 11). Furthermore, little data have been published on the prehospital use of whole blood either when collected and transfused “warm” in field conditions (i.e., “buddy transfusions”) or when it has been collected in controlled environments, properly stored, and then transfused in prehospital field settings.

The successful use of buddy transfusions, using WWB, performed during the past 12 years of conflict in Iraq and Afghanistan has been published (12, 13). In addition, an innovative use of buddy transfusion in a unique remote environment has also been established for the treatment of nontraumatic hemorrhagic shock on board Royal Caribbean Cruiseliners, where prolonged evacuation times (>6 h) to land-based medical treatment facilities are typical. Because critical bleeding events are uncommon in this setting, it would be prohibitively costly to maintain on-board stores of components and almost impossible to anticipate blood product needs. Within a 3-year period, 37 patients with hemorrhagic shock have been transfused with whole blood collected “on scene” for life-threatening hemorrhagic shock, most commonly as a result of gastrointestinal bleeding, while aboard Royal Caribbean Cruiseliners (14). The criterion for WWB transfusion by Royal Caribbean Cruiseline providers is hemodynamic instability in the presence of hemorrhage, with relative anemia. This has been a successful program because of proper planning and frequent medical staff training to maximize efficiency and safety. To optimize successful use of WWB/CWB in combat field environments, a similar approach will be required. Combat medics will need proper protocol-based guidance, education, and training if whole-blood collection and transfusion are to be successfully performed far forward, when evacuation to military treatment facilities is delayed.

In this article, we present the Norwegian Naval Special Operation Commando unit-specific RDCR protocol, which includes field collection and transfusion of whole blood. This protocol can be a template for others to use and adjust for their own military or civilian unit-specific needs and capabilities for care in austere environments.

NORWEGIAN NAVAL SPECIAL OPERATION COMMANDO RDCR PROTOCOL FOR WHOLE BLOOD

This protocol explains in detail the procedures to follow for collecting and administering whole blood in austere environments. The overall purpose and goal are to provide the best treatment possible for the wounded soldier in the safest and most effective way. One must never forget that there are several pitfalls in the administration of whole blood; therefore, it is imperative to follow this protocol when in need of a whole-blood transfusion on the battlefield.

In this protocol, the term “warm whole blood” is used when the blood is maintained at 22°C to 26°C after donation. If the donated blood is cooled to 2°C to 6°C, it is referred to as “cold-stored whole blood.” Whole blood stored for less than 48 h is referred to as “fresh.” All other blood products, such as platelets, plasma, or packed RBCs, are referred to as blood components. Quick reference and standardized equipment lists for the NORVASC RDCR protocol are displayed in Figures 2 and 3. The equipment list is a current list of devices and not an endorsement of any specific product or company. It is simply the equipment being used at the moment. This list is subject to change. The clinically relevant Frequently Asked Questions(FAQ) are highlighted in Figure 4.

Frequently Asked Questions (FAQ)

1) Should one draw more than one unit from the same donor?

Donating 2 units from one soldier will put the entire team at risk and is not recommended.

2) Can the medic donate himself?

One unit is acceptable²⁰.

3) Can personnel from other units or local nationals be used as donors?

If one knows that certain other units will be frequently encountered on the same missions, it is preferable to do as much as of the preparation regime described above for these personnel. If this has not been done, a quick test for blood type and infectious transmitted diseases is MANDATORY. Utilizing personnel that have not completed the preparation regime will increase the risk of transfusing incompatible blood or conveying infectious transmittable diseases.

4) The blood bag is not filled completely?

The bag needs at least to be 2/3 full to be utilized.

5) Can buddy transfusion be carried out with improvised equipment?

NO.

6) I overheated the blood, can I use it? Alternatively, if blood was accidentally frozen, can I use it?

NO, to both. Overheating and freezing both cause lysis of red cells and will result in serious transfusion reactions (possibly fatal).

7) If collection bag has been exposed for temperature below freezing point can I use it?

Check the bag for breakage. If still intact, it can be used if that is the only option and no other collection bags are available.

8) When should I stop a transfusion due to infusion reaction?

If signs of anaphylaxis (drop in blood pressure, loss of airway with stridor, loss of vital signs, hives) develop, stop the transfusion. Consider administration of epinephrine. Also, if the patient is conscious and complains of NEW chest pain or tightness, flank pain or other serious symptoms, stop transfusion as this may indicate a hemolytic transfusion reaction. In general, transfusion should be stopped for fever and rigors, though this may difficult to appreciate in a trauma patient suffering from hemorrhagic shock and polytrauma.

9) If I have only one intravenous/osseous access point, can I use the same line for blood and drugs?

In general, it is preferable to infuse blood products and drugs through separate lines; however, clinical and tactical situations may make this impossible. Normal saline and plasmalyte are compatible with red blood cells. Lactated Ringers and D5W should be avoided as these can cause clotting and hemolysis, respectively.

If small volumes of drugs must be given through lines carrying blood, consider flushing with isotonic saline before and after drug administration. Morphine and ketamine can probably be safely given concurrently with blood administration²¹.

10) If called upon to perform blood transfusion between host population military or civilians, are there any pitfalls to be avoided?

In general, this should be avoided unless blood typing and TTD testing are available. Avoid consanguineous transfusion as this may increase the risk of transfusion-associated graft versus host disease (rare, but fatal).

FIG. 4. Clinically relevant frequently asked questions.

Rationale

Reasons for this protocol are the following:

- A. Development of oxygen debt will, if not halted, lead to death.
- B. Red blood cells are the only oxygen-carrying cells circulating and are needed to halt and repay oxygen debt.
- C. Repayment of oxygen debt should start as early as possible after traumatic hemorrhage.
- D. Coagulopathy associated with traumatic hemorrhage increases mortality and should be addressed as soon as possible after trauma.
- E. Red blood cells, plasma, and platelets are needed for clot formation.

Consideration of these facts leads to the conclusion that whole blood should be transfused in situations of life-threatening hemorrhage, particularly when standard blood components are unavailable.

Two methods for utilization of whole blood

A. Buddy transfusion

Personnel on the scene draw one unit of blood from a fellow soldier and subsequently administer it to the wounded soldier. Blood should be transfused as soon as possible after collection (within 6 h) as WWB or, if possible, stored at 2°C to 6°C as CWB if not used within this time frame.

B. Prepermission donated blood/field blood bank

An established walking blood bank at the mission launch site donates whole blood. This blood is then preferably leukoreduced with a platelet-sparing filter and stored refrigerated at 2°C to 6°C. The combatant unit then brings stored whole blood on specific missions in Golden Hour boxes or equivalent containers to ensure temperature stability. With an unbroken cold chain,

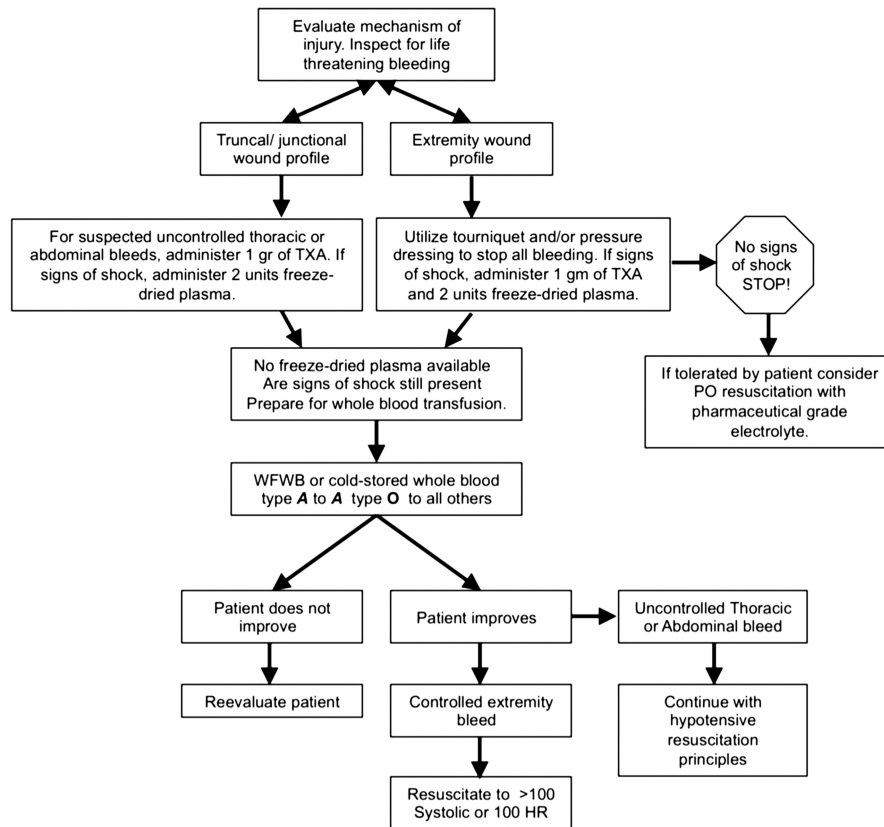


FIG. 5. Flowchart.

leukoreduced whole blood (in citrate phosphate dextrose [CPD]) can be stored for 21 days. Based on current literature, the *in vitro* hemostatic properties are well preserved for at least 10 days, so it is preferable to use stored whole blood within this time frame (9, 15). Older units (up to 21 days) will have reduced function of RBCs, plasma coagulation factors, and platelets but would still be preferred to a crystalloid-based resuscitation for patients with life-threatening hemorrhage. Whole-blood storage temperature should be monitored continuously. If the cold chain has been compromised, there is an increased risk of bacterial contamination. These CWB units should not be used unless there is no other option for a casualty at immediate risk of death.

Blood safety

To establish this protocol and to have whole blood available as a far-forward resuscitation option, several precautions and preparations must be implemented.

Preparations—All unit personnel must attend a 1-day training program. This program emphasizes the importance of only using whole blood as a measure when it is truly needed (life-threatening hemorrhagic shock). It emphasizes the importance of blood typing and knowing one's own blood type. In general, it spreads awareness of this procedure and its possible complications. Combat medics must attend a 1-week training program. Unit-specific programs are recommended. Units should consider refresher training on a routine basis (at least twice a year) because this technique is a perishable skill.

Screening—All personnel must be screened according to national safety standards for the detection of transfusion-

transmittable diseases (TTDs), such as hepatitis B and C and HIV. Personnel ABO blood type must be analyzed by a certified laboratory routinely performing these tests. As an inherent part of the blood type, persons with blood type O have in their plasma so-called regular blood type antibodies, anti-A and anti-B. The levels of these antibodies may vary and, if in high levels, may adversely interact with recipients of type O blood. A certified blood type laboratory should determine this level and report it in titers. A titer value is the reciprocal value of the highest dilution of a serum tested for an antibody. Despite the fact that there is no international consensus on the definition of a low titer, neither regarding the method of titration nor regarding the actual value for a low titer, there is a general agreement to, if possible, use type O blood from "low-titer" donors for non-type O patients or patients where the blood type cannot be confidently determined (16). As an example, the Swedish military uses the following: A and B antibody titers less than 100 for IgM and 400 for IgG type antibodies. Determination of ABO titers is highly recommended for whole-blood transfusion programs that intend to use of type O to patients other than those who are type O.

Screening of TTDs, anti-A/anti-B titer in blood type O, and ABO type is performed in the predeployment garrison setting and maintained in medical records. Each individual soldier carries a field donor card that includes this information.

When forces are deployed, a repeat test of TTDs and ABO blood type is performed to verify all medical records. In addition, a standard blood donor interview will be performed after entering the combat theater. This approach will be followed by Norwegian Naval Special Operation Commando (NORNAVSO)

but could be modified to meet specific unit operational security requirements (e.g., a discreet compatibility team chart).

Vaccination—All personnel must undergo the standard vaccination program according to the national standard for deployed personnel.

Procedure—It is important to follow precisely the specific procedures described here to ensure patient safety. The training program emphasizes the importance of identifying the patient's and the donor's blood types with 100% accuracy. Double checking and proper marking of the collection bag are underlined throughout the procedure as important measures to assure which blood type is administered.

Marking—All personnel should carry a field donor card as previously mentioned. The responsible medic will also carry a medical record that indicates the blood types of his/her team members. In the Tactical Operations Center, the same record of all soldiers' blood types should be available to supporting medical staff and commanders. Permanent marking, that is, tattoo, is also an option for all personnel. The precise format of record keeping can be modified to meet specific unit operational security requirements.

Initiation of the RDCR protocol (Fig. 5)

Indication: Clinical judgment that patient is in hemorrhagic shock (some indicators listed below)

1. Mechanism of injury compatible with severe hemorrhage (e.g., penetrating torso injury/traumatic above-knee amputation or visible massive bleeding)
2. Radial pulse greater than 120 beats/min or weak/absence of radial pulse
3. Altered mental status without head injury
4. Where such monitoring is available:
 - Single reading of systolic blood pressure of less than 90 mmHg
 - Lactate reading of more than 5 mmol/L
 - StO₂ less than 65% (17)

Mechanism of injury in combination with 2, 3, or 4 is sufficient to initiate the protocol.

When a casualty presents with signs of hemorrhagic shock, administer 1 g of tranexamic acid and two single units of a universal lyophilized plasma product, if available, before considering whole-blood transfusion. The use of plasma as initial resuscitation is grounded in the analyses of recent experience in treating civilian and combat trauma, which suggests that crystalloid resuscitation contributes to dilatational coagulopathy (18). Use of lyophilized plasma, the standard of care in World War II, may be less likely to worsen coagulopathy, although a dose of two units will not reverse an established coagulopathy. Outcomes data on the prehospital use of plasma are lacking, although studies sponsored by the US Department of Defense are ongoing. In the interim, an extrapolation from the DCR paradigm of trauma care as widely practiced seems reasonable.

Step-by-step protocol

Buddy transfusion—

- a. Identify the patient's blood type. The preferable method of identifying a patient's blood type in prioritized order is:

1. Permanent marking, for example, tattoo, double checked against field donor card if available
2. On-site typing by Eldon card or other approved device if available
3. Responsible medic's medical records, double checked against personal field donor card
4. Callback to operations and retrieved from official medical records

Follow the guidance in Figure 1 and screening procedure above regarding ABO type of the whole blood transfused.

- b. After identifying the patient's blood type, find a suitable donor. The donor must be identified by the same principles as the patient's blood type.

Give whole-blood type A donors to type A recipients and whole-blood type O donors to all other types (e.g., AB).

- c. Every soldier carries one collection bag; first use the patient's bag if it is intact and in-date. The bag should be a single packed blood bag with CPD or CPDA-1 anticoagulant mixture in it. The donor marks the bag clearly with his/her first name, blood type, call sign, and date and time group. This should be done with a marker pen on the white label of the collection bag. The person who will perform the needle puncture and collect the blood reads out what is written on the label and confirms it with the donor. If anything is wrong or poorly written, it must be corrected.
- d. A venous restriction band is applied on the upper arm of the donor to increase venous pressure; this is kept on during blood collection. A single overhand knot is made but not tightened on the plastic tube from the needle to the blood bag before the venous puncture is done. The donor should preferably be in a sitting position.
- e. The needle puncture is performed preferably on vena cubiti. Wash the puncture site with alcohol, hold the needle with bevel up, and puncture the vein in one determined movement. Introduce the needle approximately 10 mm into the vein and secure it. If the puncture is successful, blood will flow into the blood bag.
- f. During donation, the donor, if able, should drink at least 0.5 L of water, preferably more. If available, a pharmaceutical-grade oral rehydration solution should be consumed.
- g. After the needle puncture, keep the blood bag continuously in motion. This is to ensure that the blood and the additive solution are well mixed and to observe that the bag is filling. Hold collection bag in hand if possible to prevent direct contact with extremes of temperature. The bag should be situated at least 20 cm below the puncture site. A small tipping weight with a counterweight of 485 g or a measured paracord around the blood bag can be used to mark when the bag is filled with 450 mL of blood. Underfilling the bag can cause citrate toxicity and overfilling can cause clotting in the bag. In general, the goal is to fill the bag to a minimum volume of about 400 mL (450 mL \pm 10%). The goal level with acceptable limits can be measured on test bags and premarked on bags carried on operations to facilitate estimation of adequate filling. When the bag is filled, remove the needle from

the donor arm, allowing any blood in the line to run into the bag, and tighten the knot on the plastic tube as closely to the bag as is feasible (maximizing all blood and anticoagulant mixing). The responsible medic once again double checks the required blood type with the one marked on the bag. If blood bag is exposed to extremes of cold temperature and is cold to touch, use a blood warmer. If patient is in extremis and a blood warmer is unavailable, use body heat if possible to mitigate cooling and administer blood.

- h. Use an approved blood transfusion set with a filter in the drip chamber to administer the blood. The administration can be via either intravenous or intraosseous access (gauge is immaterial) (19). Be cautious when introducing the drip chamber into the blood bag; the blood bag can be damaged and start to leak if done incorrectly. Y-infusion sets are not needed. If using a Y-infusion set, do not spike a normal saline bag—run whole blood alone.
- i. Infuse by gravity only (no pressure bag and no squeezing of bag). Hypotensive resuscitation is the standard to strive for when treating hemorrhagic shock. Palpable radial pulse is a marker of roughly 80 mmHg systolic blood pressure. After this is established, the goal is to not raise the pressure too much to avoid “popping the clot.” Quantity and rate of blood administration need to be based on the clinical judgment of the responsible practitioner; hypotensive resuscitation principles are guidelines. Remember that this treatment is only buying time and keeping the patient alive until reaching a definitive treatment site. Things to take into consideration are patient response to treatment, expected time to evacuation, available donors or blood bags, and the tactical situation.

If more than one unit of blood is needed, find another appropriate donor and repeat the procedure. A donor should only donate one unit of whole blood; postdonation performance studies show minimal degradation of capabilities (20). The consequences of donating two units of whole blood are poorly documented. This decision should only be undertaken after consultation with both the tactical commander and senior medical provider on the ground, with the realization you might be creating another impaired patient.

- j. If the blood is not used immediately, store at room temperature (22°C – 26°C) for a maximum of 6 h, then store at 2°C to 6°C. After this procedure, the blood can be used for up to 21 days but is preferably used within 10 days (see Fig. 3. Permission donated blood). It can be stored at room temperature for up to 24 h (22°C) but should be discarded thereafter.
- k. The transfusion must be registered according to unit-specific procedures and, it is advisable to keep the blood bag with the patient during transport to the surgical facility as documentation and also to follow up TTD testing after transfusion.

Predonated blood/field blood bank

When it is feasible, a team can be equipped with an amount of leukoreduced predonated blood stored in Golden Hour or equivalent containers at 2°C to 6°C. The donors for this blood are personnel available in the forward operating base who

have completed the unit's preparation, screening, and vaccination program and have been included in an established “walking blood bank.” The establishment of a walking blood bank is done after a separate protocol and will not be discussed here. The predonated blood units are valid for 10 days as long as the cold chain is preserved. We recommend using low-titer type O whole blood.

- a. Identify the patient's blood type.

Follow same steps as in buddy transfusion 5.1a

- b. Retrieve a blood bag from the Golden Hour container. Preferably only low-titer type O in the Golden Hour container.
- c. If a fluid warmer is available, the blood should be warmed before infusion.

Avoid using an improvised system for heating the whole blood.

- d. Use an approved blood transfusion set with a filter in the drip chamber to administer the blood.

If the patient needs more than one unit of blood, use the predonated blood bags first. If those are not enough, consider performing a buddy transfusion procedure. Follow the guidance in the Special Considerations (Fig. 1) and Screening Procedures regarding ABO type of the whole blood transfused.

- e. If a bag is removed from the container for a short period (<20 min) but not used, put it back in, and if the cold chain is preserved, it can still be used until it expires on day 10 of storage.

Type-specific whole blood versus universal whole-blood type O transfusion

We *strongly* advise the following rules be followed.

- a.) If recipient blood type is not verified, always transfuse whole-blood type O.

Whole-blood type O low titer is the preferable universal whole blood—if titer is unknown, type O is still recommended if type specific is not available. Remember, risk of death from exsanguination (definite) exceeds risk of death from hemolysis (possible).

- b.) Whole-blood type A donors to A recipients and whole-blood type O donors to all other types (e.g., AB).

If starting with whole-blood type O—recommended to continue with whole-blood type O

If starting with type A specific and no more type A specific available—continue with whole-blood type O.

- c.) In-hospital, type-specific whole-blood transfusion is preferred (the casualty receives whole blood with the same ABO type as him/herself).

In chaotic emergent situations (far-forward locations/ combat), ABO incompatibility is the most feared complication and is potentially fatal. Historically, whole-blood type O has been used in emergency situations to avoid this complication. Risk of hemolytic transfusion reaction in the recipient is reduced by using low-titer whole-blood O. A defined amount of

antibodies against blood types A and B in donors with type O is set to define what is low and high titer. There is no international standardization of this titer, and until this has been agreed on, national standards have to be followed regarding what is defined as "low-titer O." If anti-A and anti-B titer is unknown, it is still advisable to use donor type O. Risk of a fatal hemolytic transfusion reaction because of transfusion of high-titer whole-blood type O to non-type O recipients is still very low compared with the mortality risk facing casualties in hemorrhagic shock prehospital (16).

CONCLUSIONS

Military experience and recent *in vitro* laboratory data provide a biological rationale for whole-blood use in the treatment of exsanguinating hemorrhage and have renewed interest in the reintroduction of WWB and CWB (5, 8, 9). In austere environments, for casualties with life-threatening hemorrhage, it is appropriate to consider a whole blood-based resuscitation approach to provide a balanced response to altered hemostasis and oxygen debt, with the goal of reducing the risk of death from hemorrhagic shock. To optimize the successful use of WWB/CWB in combat field environments, proper planning and frequent training to maximize efficiency and safety will be required. Combat medics will need proper protocol-based guidance, education, and training if whole-blood collection and transfusion are to be successfully performed far forward, when evacuation to military treatment facilities is delayed (Fig. 5).

REFERENCES

- Spinella PC: Warm fresh whole-blood transfusion for severe hemorrhage: US military and potential civilian applications. *Crit Care Med* 36(Suppl 7): S340–S345, 2008.
- Eastridge BJ, Mabry RL, Seguin P, Cantrell J, Tops T, Uribe P, Mallet O, Zubko T, Oetjen-Gerdes L, Rasmussen TE, et al.: Death on the battlefield (2001–2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg* 73(6 Suppl 5):S431–S437, 2012.
- Spinella PC, Holcomb JB: Resuscitation and transfusion principles for traumatic hemorrhagic shock. *Blood Rev* 23(6):231–240, 2009.
- Gerhardt RT, Strandenes G, Cap AP, Rentas FJ, Glassberg E, Mott J, Dubick MA, Spinella PC; THOR Network and RemTORN Study Groups: Remote damage control resuscitation and the Solstrand Conference: defining the need, the language, and a way forward. *Transfusion* 53(Suppl 1):9S–16S, 2013.
- Spinella PC, Perkins JG, Grathwohl KW, Beekley AC, Holcomb JB: Warm fresh whole blood is independently associated with improved survival for patients with combat-related traumatic injuries. *J Trauma* 66(Suppl 4):S69–S76, 2009.
- Neel MGS: Vietnam Studies: Medical Support of the US Army in Vietnam 1965–1970. Department of the Army; 1991. Available at: <http://history.amedd.army.mil/booksdocs/vietnam/medicalsupport/default.html>. Accessed November 1, 2013.
- Douglas B, Kendrick M: United States Army Medical Department in World War II: Blood Program in World War II 1964. Available at: <http://history.amedd.army.mil/booksdocs/wwii/blood/default.htm>. Accessed November 1, 2013.
- Nessen SC, Eastbridge BJ, Cronk D, Craig RM, Berseus O, Ellison R, Remick K, Seery J, Shah A, Spinella PC: Fresh whole blood use by forward surgical teams in Afghanistan is associated with improved survival compared to component therapy without platelets. *Transfusion* 53(Suppl 1):107S–113S, 2013.
- Pidcock HF, McFaul SJ, Ramasubramanian AK, Parida BK, Mora AG, Fedyk CG, Valdez-Delgado KK, Montgomery RK, Reddoch KM, Rodriguez AC, et al.: Primary hemostatic capacity of whole blood: a comprehensive analysis of pathogen reduction and refrigeration effects over time. *Transfusion* 53(Suppl 1): 137S–149S, 2013.
- Perkins JG, Cap AP, Spinella PC, Blackburn LH, Grathwohl KW, Repine TB, Ketchum L, Waterman P, Lee RE, Beekley AC, et al.: An evaluation of the impact of apheresis platelets used in the setting of massively transfused trauma patients. *J Trauma* 66(Suppl 4):S77–S84, 2009.
- Pidcock HF, Aden JK, Mora AG, Borgman MA, Spinella PC, Dubick MA, Blackburn LH, Cap AP: Ten-year analysis of transfusion in Operation Iraqi Freedom and Operation Enduring Freedom: increased plasma and platelet use correlates with improved survival. *J Trauma Acute Care Surg* 73(6 Suppl 5): S445–S452, 2012.
- Malsby R 3rd, Frizzi J, Ray P, Raff J: Walking donor transfusion in a far forward environment. *Southern Med J* 98(8):809–810, 2005.
- Cordova CB, Cap AP, Spinella PC: Case report: fresh whole blood transfusion for a combat casualty in austere combat environment. *J Special Operations Med* 14(1):9–12, 2014.
- Hooper TJ, Nadler R, Badloe J, Butler F, Glassberg E: Implementation and execution of military forward resuscitation programs. *Shock* 41(Suppl):90–97, 2014.
- Jobes D, Wolfe Y, O'Neill D, Calder J, Jones L, Sesok-Pizzini D, Zheng XL: Toward a definition of "fresh" whole blood: an *in vitro* characterization of coagulation properties in refrigerated whole blood for transfusion. *Transfusion* 51(1):43–51, 2011.
- Berseus O, Boman K, Nessen SC, Westerberg LA: Risks of hemolysis due to anti-A and anti-B caused by the transfusion of blood or blood components containing ABO-incompatible plasma. *Transfusion* 53(Suppl 1):114S–123S, 2013.
- Hampton DA, Schreiber MA: Near infrared spectroscopy: clinical and research uses. *Transfusion* 53(Suppl 1):52S–58S, 2013.
- del Junco DJ, Holcomb JB, Fox EE, Brasel KJ, Phelan HA, Bulger EM, Schreiber MA, Muskat P, Alarcon LH, Cohen MJ, et al.: Resuscitate early with plasma and platelets or balance blood products gradually: findings from the PROMITT study. *J Trauma Acute Care Surg* 75(1 Suppl 1):S24–S30, 2013.
- Tocantins LM, O'Neill JF, Price AH: Infusions of blood and other fluids via the bone marrow in traumatic shock and other forms of peripheral circulatory failure. *Ann Surg* 114(6):1085–1092, 1941.
- Strandenes G, Skogrand H, Spinella PC, Hervig T, Rein EB: Donor performance of combat readiness skills of special forces soldiers are maintained immediately after whole blood donation: a study to support the development of a prehospital fresh whole blood transfusion program. *Transfusion* 53(3):526–530, 2013.
- Birch C, Hogan C, Mahoney G: Coadministration of drugs and blood products. *Anaesth Intensive Care* 29(2):137–140, 2001.

